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Quarterly Report

No. 2

LIFAC Sorbent Injection Desulfurization Demonstration Project

Presented By

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A Joint Venture Between

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LIFAC Sorbent Injection Desulfurization Demonstration Project

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INTRODUCTION

In December 1990, the U.S. Department of Energy selected 13 projects for funding under the Federal Clean Coal Technology Program (Round III). One of the projects selected was the project sponsored by LIFAC North America, (LIFAC NA), titled "LIFAC Sorbent Injection Desulfurization Demonstration Project." The host site for this $17 million, three-phase project is Richmond Power and Light's Whitewater Valley Unit No. 2 in Richmond, Indiana. The LIFAC technology uses upper-furnace limestone injection with patented humidification of the flue gas to remove 75-85% of the sulfur dioxide (SO_2) in the flue gas.

In November 1990, after a ten (10) month negotiation period, LIFAC NA and the U.S. DOE entered into a Cooperative Agreement for the design, construction, and demonstration of the LIFAC system. This report is the second Technical Progress Report covering the period January 1, 1991 through the end of March 1991. Due to the power plant's planned outage schedule, and the time needed for engineering, design and procurement of critical equipment, DOE and LIFAC NA agreed to execute the Design Phase of the project in August 1990, with DOE funding contingent upon final signing of the Cooperative Agreement.

BACKGROUND

Project Team

The LIFAC demonstration at Whitewater Valley Unit No. 2 is being conducted by LIFAC North America, a joint venture partnership between:

- ICF Kaiser Engineers - A U.S. company based in Oakland, California, and a subsidiary of ICF International (ICF) based in Fairfax, Virginia.

- Tampella Power Corp. - A U.S. subsidiary of a large diversified international company, Tampella Corp., based in Tampere, Finland and the original developer of the LIFAC technology.

LIFAC NA is responsible for the overall administration of the project and for providing the 50 percent matching funds. Except for project administration, however, most of the actual work is being performed by the two parent firms under service agreements with LIFAC NA. Both parent firms work closely with Richmond Power and Light and the other project team members, including ICF Resources, the Electric Power Research Institute (EPRI), Indiana Corporation for Science and Technology (ICS&T), Peabody Coal Company, and Black Beauty Coal Company. LIFAC NA is having ICF Kaiser Engineers manage the demonstration project out of its Pittsburgh office, which provides excellent access to the DOE representatives of the Pittsburgh Energy Technology Center. Figure 1 shows the management structure being used throughout the three phases of the project.

LIFAC NA administers the project through a Management Committee that decides the overall policies, budgets, and schedules. All funding sources, invoicing, and information flows to LIFAC NA where the managing partners ensure that the project, funding and expenditures are consistent and in-line with the established policies, budgets, schedules and procedures.

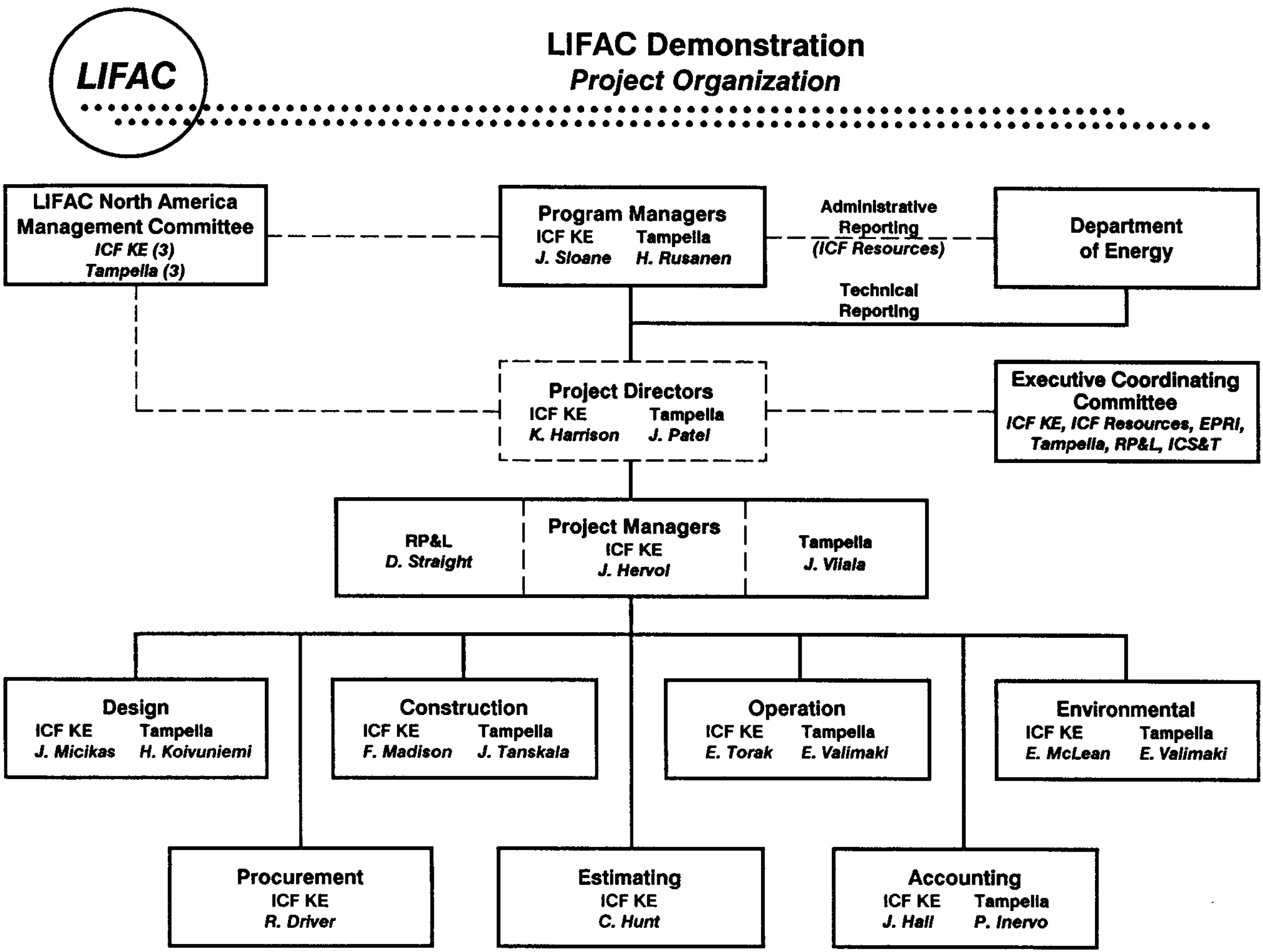
Process Development

In 1983, Finland enacted acid rain legislation which applied limits on SO_2 emissions sufficient to require that flue gas desulfurization systems have the capability to remove about eighty percent (80%) of the sulfur dioxide in the flue gas. This level could be met by conventional scrubbers, but could not be met by then available sorbent injection technology. Therefore, Tampella began developing an alternative system which resulted in the LIFAC process.

Initially, development included laboratory-scale and pilot-plant tests. Full-scale limestone injection tests were conducted at Tampella's Inkeroinen facility, a 160 Mwe coal-fired boiler using high-ash, low-sulfur Polish coal. At Ca:S ratios of 3.1, sulfur removal was less than 50%. Better results could have been attained using lime, but was rejected because the cost of lime is much higher than that of limestone.

In-house investigations by Tampella led to an alternative approach involving humidification in a separate vertical chamber which became known as the LIFAC Process. In cooperation with Pohjolan Voima Oy, a Finnish

LIFAC Demonstration
Project Organization



utility, Tampella installed a full-scale limestone injection facility on a 220 Mwe coal-fired boiler located at Kristiinankaupunki. At this facility, a slipstream (5000 SCFM) containing the calcined limestone was used to test a small-scale activation reactor (2.5 MW) in which the gas was humidified. Reactor residence times of 3 to 12 seconds resulted in SO_2 removal rates of 84%. Additional LIFAC pilot-scale tests were conducted at the 8 Mwe (thermal) level at the Neste Kulloo combustion laboratory to develop the relationships between the important operating and design parameters. Polish low-sulfur coal was burned to achieve 84% SO_2 removal.

In 1986, full-scale testing of LIFAC was conducted at Imatran Voima's Inkoo power plant on a 250 Mwe utility boiler. An activation chamber was built to treat a flue gas stream representing about 70 Mwe. Even though the boiler was 250 Mwe, the 70 Mwe stream represented about one-half of the flue gas feeding one of the plant's two EPSs (i.e., each ESP receives a 125 Mwe gas stream). This boiler used a 1.5% sulfur coal and sulfur removal was initially 61%. By late 1987, SO_2 removal rates had improved to 76%. In 1988, a LIFAC activation reactor was added to treat an additional 125 Mwe -- i.e., an entire flue gas/ESP stream-worth of flue gas from this same boiler. This newer activation reactor is achieving 75-80% SO_2 removal with Ca:S ratios between 2:1 and 2.5:1. In 1988, the first tests using high-sulfur U.S. coals were run at the pilot scale at the Neste Kulloo Research Center, using a Pittsburgh No. 8 coal containing 3% sulfur. SO_2 removal rates of 77% were achieved at a Ca:S ratio of 2:1.

This LIFAC demonstration project will be conducted on a 60 Mwe boiler burning high-sulfur U.S. coals to demonstrate the commercial application of the LIFAC process to U.S. utilities.

Process Description

LIFAC combines upper-furnace limestone injection followed by post-furnace humidification in an activation reactor located between the air preheater and the ESP. The process produces a dry and stable waste product that is partially removed from the bottom of the activation reactor and partially removed at the ESP.

Finely pulverized limestone is pneumatically conveyed and injected into the upper part of the boiler. Since the temperatures at the point of injection are in the range of 1800-2000° F, the limestone ($CaCO_3$) decomposes to form lime (CaO). As the lime passes through the furnace, initial desulfurization reactions take place. A portion of the SO_2 reacts with the CaO to form calcium sulfite ($CaSO_3$), part of which then oxidizes to form calcium sulfate ($CaSO_4$). Essentially all of the sulfur trioxide (SO_3) reacts with the CaO to form $CaSO_4$.

The flue gas and unreacted lime exit the boiler and pass through the air preheater. On leaving the air preheater, the gas/lime mixture enters the patented LIFAC activation reactor. In the reactor, additional sulfur dioxide capture occurs after the flue gas is humidified with a water spray. Humidification converts lime (CaO) to hydrated lime, $Ca(OH)_2$, which enhances further SO_2 removal. The activation reactor is designed to allow time for effective humidification of the flue gas, activation of the lime, and reaction of the SO_2 with the sorbent. All the water droplets evaporate before the flue gas leaves the activation reactor. The activation reactor is also designed specifically to minimize the potential for solids build-up on the walls of the chamber. The net effect is that at a Ca:S ratio in the range of 2:1 to 2.5:1, 70-80% of the SO_2 is removed from the flue gas.

The flue gas leaving the activation reactor then enters the existing ESP where the spent sorbent and fly ash are removed from the flue gas and sent to the disposal facilities. ESP effectiveness is also enhanced by the humidification of the flue gas. The solids collected by the ESP consist of fly ash, $CaCO_3$, $Ca(OH)_2$, CaO, $CaSO_4$, and $CaSO_3$. To improve utilization of the calcium, and increase SO_2 reduction to between 75 and 85%, a portion of the spent sorbent collected in the bottom of the activation reactor and/or in the ESP hoppers is recycled back into the ductwork just ahead of the activation reactor.

Process Advantages

The LIFAC technology has similarities to other sorbent injection technologies using humidification, but employs a unique patented vertical reaction chamber attached to the down-stream sections of the boiler to facilitate and control the sulfur capture and other chemical reactions. This chamber improves the overall reaction efficiency enough to allow the use of pulverized limestone rather than more expensive reagents such as lime which are often used to increase the efficiency of other sorbent injection processes.

Sorbent injection is a potentially important alternative to conventional wet lime and limestone scrubbing, and this project is another effort to test alternative sorbent injection approaches. In comparison to wet systems, LIFAC, with recirculation of the sorbent, removes less sulfur dioxide - 75-85% relative to 90% or greater for conventional scrubbers - and requires more reagent material. However, if the demonstration is successful, LIFAC will offer these important advantages over wet scrubbing systems:

- LIFAC is relatively easy to retrofit to an existing boiler and requires less area than conventional wet FGD systems.

- LIFAC is less expensive to install than conventional wet FGD processes.

- LIFAC's overall costs measured on a dollar-per-ton SO_2 removed basis are less, an important advantage in a regulatory regime with trading of emission allocations.

- LIFAC produces a dry, readily disposable waste by-product versus a wet product.

- LIFAC is relatively simple to operate.

HOST SITE DESCRIPTION

The site for the LIFAC demonstration is Richmond Power and Light's Whitewater Valley 2 pulverized coal-fired power station (60 MWe), located in Richmond, Indiana. Whitewater Valley 2, which began service in 1971, is a Combustion Engineering tangentially-fired boiler which uses high-sulfur bituminous coal from Western Indiana. Actual power generation produced by the unit approaches 65 megawatts. As such, it is one of the smallest existing, tangentially-fired units in the United States. The furnace is 26-feet, 11-inches deep and 24-feet, 8-inches wide. It has a primary and secondary superheater. Tube sizes and spacings are designed to achieve the highest possible heat-transfer rates with the least potential for gas-side fouling. The unit also has an inherent low draft-loss characteristic because of the lack of gas turns. At full load 540,000 lbs/hr. of steam are generated. The heat input at rated capacity is 651 x 10^6 Btu per hour. The design superheater outlet pressure and temperature are 1320 psi at 955°F. The unit has a horizontal shaft basket-type air preheater. The temperature leaving the economizer is about 645°F, while the flue gas temperature is about 316°F. The balanced-draft unit has 12 burners.

In 1980 the unit was fitted and fully optimized with a state-of-the-art Low-NO_x Concentric Firing System (LNCFS). The LNCFS represents a very cost effective means of reducing NO_x emissions in comparison with other retrofit possibilities. The system works on the principal of directing secondary air along the sides of the furnace and creating a fuel rich zone in the center of the furnace. With the LNCFS, the excess air can be maintained below 20 percent. Additionally, the installation reduces ash accumulation on the furnace walls increasing heat absorption and reducing attemperation requirements. With the LNCFS, each corner of the furnace has a tangential windbox consisting of three coal compartments and four auxiliary air compartments. At full load with all three 593 RB pulverizers operating, primary transport air from the pulverizers amounts to 23 percent of the total combustion air. Pulverizer capacity is 26,400 lbs/hr. with 52 grind coal and 70 percent minus 200 mesh.

Whitewater Unit 2 has a Lodge Cottrell cold side precipitator which was erected with the boiler. The precipitator treats 227,000 actual cubic feet per minute of 316°F flue gas with 45,000 square feet of collection area. The unit has two mechanical fields and four electrical fields and achieves 99 percent removal efficiency (from 3.9 gr/ft^3 to 0.04 gr/ft^3). The ESP performance was optimized by Lodge Cottrell when Richmond Power and Light purchased new controllers in 1985.

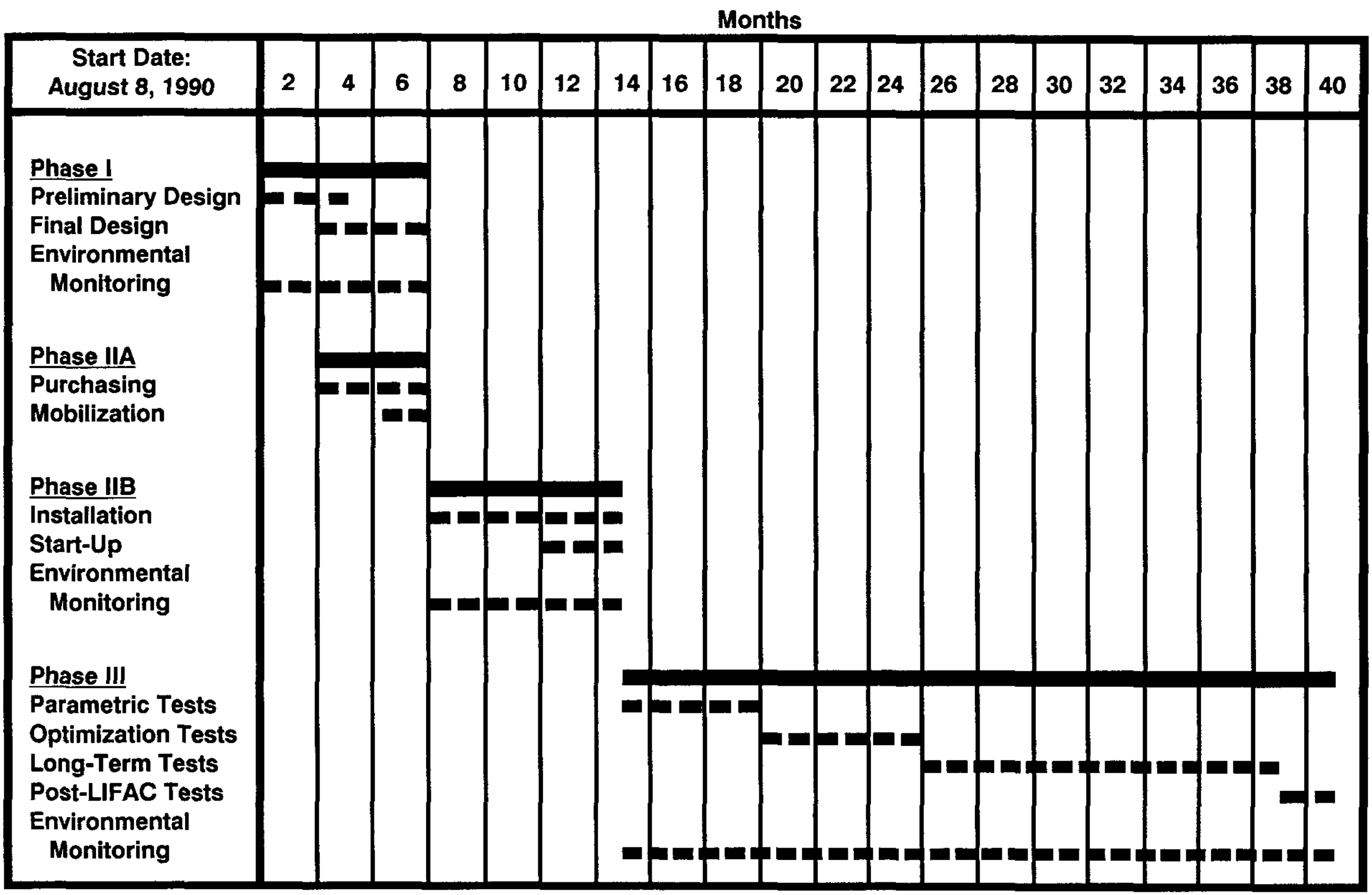
Whitewater Valley Unit 2's overall efficiency of 87.47 percent at full load has shown little variation over the years. The unit's average heat rate is 10,280 Btu/Kwh. At 60 percent of full load, the unit's efficiency increases to 88.17 percent. The unit uses approximately 0.935 pounds of coal per Kwh and generates 8.51 pounds of steam per Kwh.

The primary emissions monitored at the station are SO_2 and opacity. SO_2 emissions are calculated based on the coal analysis and are limited to 6 $lbs/10^6$ Btu. Opacity is monitored using an in-situ meter at the ESP outlet and is currently limited to 40 percent. Current SO_2 emissions for the unit are approximately 4 $lbs/10^6$ Btu, while opacity at full load ranges from 15 to 20 percent. Opacity at low load (40MW) ranges from 3 to 5 percent. Limited testing was conducted in November of 1986 for NO_x emissions. Results from the test work indicated that NO_x emissions averaged 0.65 $lbs/10^6$ Btu.

Whitewater Valley 2 has several important qualities as a LIFAC demonstration site. One of these is that Whitewater Valley 2 was the site of a prior joint EPA/EPRI demonstration of LIMB sorbent injection technology. Much of the sorbent injection equipment remains on site and will be used in the LIFAC demonstration, if possible. Another advantage of the site is that Whitewater Valley 2 is a challenging candidate for a retrofit due to the cramped conditions at the site. The plant is thus typical of many U.S. power plants which are potential sites for application of LIFAC. In addition, Whitewater Valley 2 boiler is small relative to its capacity; hence, it has high-temperature profiles relative to other boilers. This situation will require sorbent injection at higher points in the furnace in order to prevent deadburning of the reagent and may decrease residence times needed for sulfur removal. Whitewater Valley 2 will show LIFAC's performance under operational conditions most typical of U.S. power plants. The project will demonstrate LIFAC on high-sulfur U.S. coals and is a logical extension of the Finnish demonstration work and important for LIFAC's commercial success in the U.S.

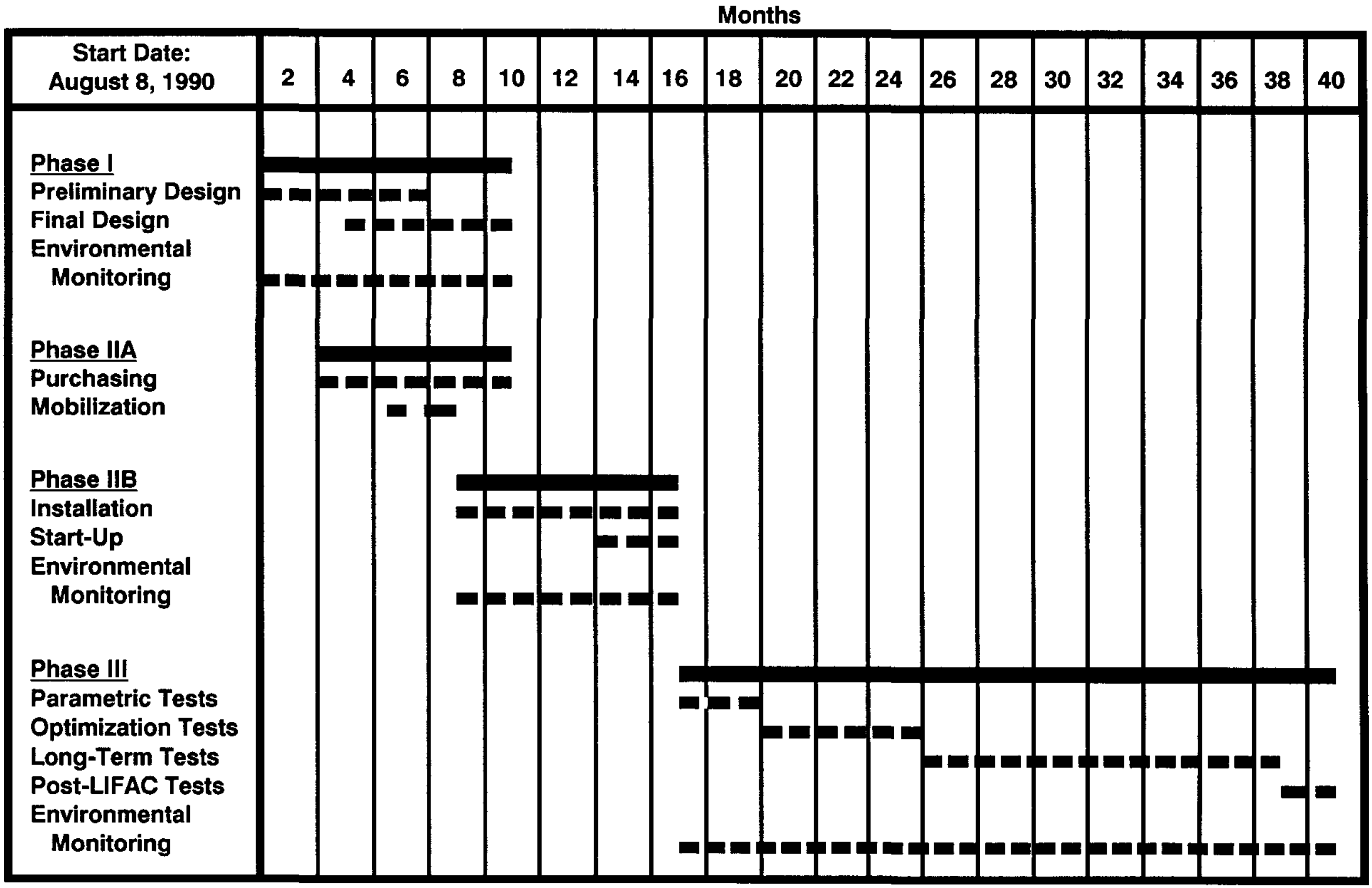
LIFAC Demonstration

Original Project Schedule



LIFAC Demonstration

Revised Project Schedule



the Design Phase (Project Management, Engineering and Design, Environmental Monitoring) and the Long Lead Procurement task and preliminary construction activities in the Construction Phase. Following is a summary of the work performed under these tasks.

Project Management (WBS 1.1.1)
During the January through March period, management efforts shifted from negotiations related to the DOE Cooperative Agreement and related documents to several other areas including:

- **Finalizing Partnership Agreements** - Tampella Power Corporation and ICF Kaiser Engineers resolved nearly all remaining issues related to the marketing, partnership and technology licensing agreements. Final execution of all agreements is expected during the next reporting period.

- **Joint LIFAC NA/DOE Cooperation** - LIFAC NA took many steps towards full implementation of the Cooperative Agreement including:

    - Conducted the first quarterly project review meeting in Pittsburgh on February 14
    - Provided preliminary drafts of two key DOE administrative reports - Cost Plan and Cost Management Report
    - Prepared and sent first invoices to DOE, and began to establish LIFAC NA accounting procedures consistent with DOE requirements
    - Worked to resolve Tampella invoicing problem
    - Presented DOE drafts of the first tier LIFAC NA subcontracts for Tampella Power Corporation, ICF Resources, ICF Kaiser Engineers, and Richmond Power and Light

    Anticipate full implementation of all remaining accounting, invoicing, and reporting requirements in next period.

- **Regulatory** - Continued efforts to obtain all necessary state permits and approvals:

- Filed testimony for obtaining a Certificate of Need and Necessity from the Indiana Utility Regulatory Commission under the state's Clean Coal Project law. Worked closely with the Commission staff, legal experts and the host utility, Richmond Power and Light. Anticipate success in obtaining the certificate or a waiver of the requirement.

- Set up meetings with Indiana Department of Environmental Management officials to outline steps related to a solid waste disposal permit (see environmental discussion elsewhere).

• **Funding Agreements** - Continued efforts to negotiate and finalize arrangements for participation/funding of other project participants:

  - Electric Power Research Institute - Met in Palo Alto with several representatives of EPRI to discuss: (1) LIFAC process parameters, (2) estimates of the costs of the commercial version of LIFAC developed by an EPRI subcontractor, (3) EPRI funding, and (4) the market potential for LIFAC among EPRI members. Agreed to provide additional information including a report on LIFAC market prospects among EPRI members; a draft report answering this request was written and is anticipated to be provided during the next period.

  - Indiana Corporation for Science and Technology (CST) - CST awarded LIFAC NA 0.8 million dollars during the previous period. LIFAC NA undertook steps to sign a contract with CST for the provision of the funding. Provided CST a new proposed contract outlining their participation in the project and arranged meeting with their representatives in Indianapolis. Expect full resolution of all outstanding issues in next period.

  - Peabody Coal Company - Scheduled negotiations with Peabody on contracts for the provision of coals during the test program.

- Black Beauty Coal Company - Scheduled negotiations with Black Beauty on contracts for the provision of coals during the test program. LIFAC NA is optimistic that contract negotiations will be successful.

- Lafarge/Limestone Company - Lafarge informed LIFAC NA that it would not be able to participate in the funding of the project due to recent financial difficulties. Lafarge, however, did indicate interest in potentially participating in the project's tests of uses for the waste and study characterization of the waste by-product. This decision was regrettable, but in no way jeopardizes the project since the partners are capable and committed to purchasing the services and materials Lafarge was to provide. Subsequently, LIFAC arranged meetings with three other limestone companies to discuss their participation in the project: (1) Mulzer, (2) Rodgers, and (3) Kosmos Cement - Southdown Corporation. We are optimistic that a replacement for Lafarge will be found.

• **Technology Transfer Activities** - Undertook technology transfer activities including preliminary planning for a ground-breaking ceremony, participation in several conferences, answering technical questions, protecting patent rights, etc.

• **Test Plan** - An internal working copy of a sampling requirements document was prepared for use in designing the LIFAC system for Whitewater Valley Unit 2. The document identified where samples will be collected and where analyzers and instrumentation should be installed. This document was used by the designers so that test/sampling ports were installed in the proper locations and by the environmental engineers in preparing the draft Environmental Monitoring Plan.

• **Management Oversight** - LIFAC NA maintained close oversight of design and the successful preliminary construction activities conducted during the planned maintenance outage at the Whitewater Valley 2 site.

Engineering and Design (WBS 1.1.2)

During this period, emphasis was placed on the completion of the March outage tie-in activities. *Tampella delivered to ICF KE in mid January* a preliminary mass balance flowsheet, updated P&ID and proposed activation reactor design concept. Other activities during this period included the layout and design of the limestone storage area, activation reactor, slag removal system, reheat system, recycle system, humidification system, and piping, electrical and instrumentation requirements.

Engineering and design activities included:

- Completion of March tie-in activities including boiler modifications; water, steam and condensate pipe tie-ins; supply and return ductwork design; ductwork hanger and support design; damper design/selection; and access platform and walkway design.

- Civil/Structural/Architectural Design emphasis included:
  - Layout and design of limestone storage area/motor control center/variable frequency drive building.
  - Design of activation reactor Support System.
  - Design of duct support/stair tower.
  - Layout and design of reactor platforms and penthouse.
  - Supply and return ductwork design outside of powerhouse.
  - Foundation design for stair tower, reactor and limestone storage building.
  - Layout and design of secondary air fan floor steel.
  - Layout and design of electrical equipment room.

- Mechanical design emphasis included:
  - Process flow diagrams
  - Mechanical arrangement of limestone storage building.
  - New Limestone silo arrangement and details
  - Design/Analysis of limestone injection system
  - Finalization of boiler injection port locations and seal box installation
  - Design of the expansion joints.
  - Completion of modifications to existing flue gas ductwork.
  - *Layout of reactor discharge equipment.*
  - Layout of spent sorbent recirculation system.

- Calculated air requirements.
- Calculated capacities of existing pneumatic transport equipment.
- Determined limestone silo and bin vent capacities.
- Calculated flue gas duct thermal expansions.
- Wrote various mechanical equipment/system specifications.

• HVAC design emphasis included:
  - Determination of heating, ventilation and air conditioning requirements of the limestone storage building, motor control center, variable frequency drive room, and electrical equipment room.
  - Sized the appropriate equipment for the above requirements.

• Piping/Vessel design emphasis included:
  - Started design of activation reactor
  - Engineering of standard pipe supports
  - Layout and design of limestone storage service air piping
  - Layout and design of secondary air and limestone pneumatic transport piping systems
  - Layout and design of spray water, compressed air, slag recycle and spent sorbent recycle P&ID
  - Completed layout and design of steam flow balance diagram
  - Completed P&ID steam/condensate diagram
  - Layout and design of steam and condensate piping system
  - Completed ESP tie-in and relocation of various existing miscellaneous piping systems
  - Wrote various piping/vessel specifications

• Electrical design emphasis included:
  - Engineering began on single line diagrams, conduit plans, lighting schedules, conduit and cable schedules and grounding plan.
  - Layout and design of activation reactor electrical general arrangement
  - Layout and design of activation reactor platform lighting and grounding
  - Layout and design of spend sorbent area conduit plan

- General plant lighting design
- Wrote various electrical specifications.

- Instrumentation design emphasis included:
  - Development of P&ID's, legends and general notes
  - Wrote various equipment/instrumentation specifications

- Specifications required for the purchase of various equipment and systems were written by the mechanical, electrical and instrumentation groups. The following is a list of the specifications written and completed during this period:
  - Power Transformers
  - 480 volt Motor Control Center and Distribution Panels
  - 4160 volt Switchgear additions
  - Humidification Water Booster Pump
  - Primary and Secondary Sorbent Splitter
  - Duplex Basket Strainer
  - Secondary Air Fan
  - Reactor Discharge Flight Conveyor/Crushers and Flight Transfer Conveyor and Accessories

- The following is a list of specifications which were reissued or started during this period:
  - Ductwork Hangers and Supports
  - Limestone Storage Silo
  - Reactor Ductwork Expansion Joints
  - Fabrication and Erection of Activation Reactor
  - Pneumatic Vibrators
  - Flue Gas Reheater
  - Sorbent Recycle Equipment
  - Pressure Indicators
  - Temperature Elements
  - Temperature Transmitters
  - Flow Elements
  - Level Switches
  - Control Valves (Manual and Motor)
  - Ultrasonic Analog Level System
  - Pressure Transmitters

- Weigh Cells
- Pilot Tube Flow Element

In January, the project design team leaders visited the existing LIFAC installations in Finland to observe construction of the new reactor at the Vantaa Power Plant and operations of the existing units at the Inkoo Plant. ICF KE and Tampella engineers also had design meetings to discuss equipment selection and materials of construction for the Richmond Power & Light project. Meetings were also held to review the potential problems/benefits/marketability of LIFAC-generated waste.

ICF KE also began to develop the process control system for LIFAC. Tampella engineers assisted in providing the control logic and interlocking description.

Environmental Monitoring (WBS 1.1.3)
Environmental activity during this quarter involved maintaining/tracking of host site permitting issues, addressing permitting issues related to the initiation of Phase I construction, and a renewed focus on the EMP.

ICF KE continued evaluation of the potential effects of unresolved air permit issues on the analyses presented in the EIV. These issues involved the status of air emissions limits and solid waste disposal issues involving existing waste streams and the future LIFAC waste streams.

ICF KE provided support to the host site in addressing whether a research-related, no-action assurance under the Clean Air Act should be pursued with IDEM and EPA. The research-related no-action assurance would insure that demonstration project modifications would not trigger a new source designation.

The planned initiation of Phase I construction activities during the March outage triggered the need to address construction permitting early in the quarter. Contact with IDEM regarding the scope of the Phase I activities, indicated that a permit application would not be required for Phase I but would be required to be submitted and obtained before Phase II construction was initiated. ICF KE prepared a letter to IDEM on January 24, 1991 documenting the basis for waiving the need for a construction permit application for Phase I activities.

In conjunction with the development of the LIFAC system design and control system monitoring requirements, activities refocused on revising and finalizing the draft EMP. Meetings were held to discuss process control monitoring and monitoring locations to clarify availability of monitoring locations and the intersection of test plan, process control, and environmental monitoring requirements.

At the request of DOE, ICF KE prepared a draft letter to Jerry Hebb of DOE on February 18th addressing IDEM issues related to potential effects of the LIFAC demonstration project on the environment at or in the vicinity of the host site.

Long Lead Procurement (WBS 1.2.1A)

During this period, bid specifications were issued for most remaining long lead items. These included:

- Limestone storage bin
- 4160 volt switchgear
- Reactor slag discharge system
- Transformers

During this period, purchase orders/subcontracts were issued for these items/activities:

- March outage construction
- ID fan variable frequency controller
- 4160 volt switchgear

During the next reporting period, all remaining long lead procurement activities will be completed.

Installation and Startup (WBS 1.2.2B)

During February and March, all tie-in requirements at Whitewater Valley Unit 2 were completed. These include:

- Adding five additional injection ports into the boiler at a higher elevation than the existing ports.
- Installing bypass ductwork and dampers.
- Installing tie-in pipes and valves on the ESP hoppers for future recycling of spent sorbent.

- Installation of tie-ins for water supply, steam supply and condensate return.
- Installing additional catwalks and landings around the boiler.
- Rerouting of existing pipes due to installation of new ductwork and dampers.

Also, during this period LIFAC NA set up a field office at the Whitewater site for use during construction and operations.

FUTURE PLANS

During the next period, LIFAC NA hopes to conclude negotiations and secure funding from the identified co-funders. This includes finding a replacement for LaFarge.

Meetings will be held with various regulatory agencies in hopes of obtaining all the necessary permits or variances needed to install and operate LIFAC at Richmond Power & Light.

Complete all detailed design and procurement of equipment needed for installation of LIFAC and issue all the required purchase orders and subcontracts needed to complete construction and startup by the end of October 1991.

Complete the next draft of the EMP and submit it to DOE for review and comment.

Submit all past due project deliverables as required under the Cooperative Agreement.